

JOURNAL OF AGRICULTURAL RESEARCH

VOL. XXV

WASHINGTON, D. C., SEPTEMBER 1, 1923

NO. 9

SPECIALIZED VARIETIES OF PUCCINIA GLUMARUM, AND HOSTS FOR VARIETY TRITICI¹

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INTRODUCTION

Since the discovery of stripe rust in the United States, in 1915, a systematic study of the disease has been conducted by the Office of Cereal Investigations of the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Oregon Agricultural Experiment Station, and, later, with the Idaho Agricultural Experiment Station. This paper is the third of a series of contributions to our knowledge of stripe rust in the United States. Former papers (2, 10)³ have dealt with the economic importance and geographical distribution of the disease and with the life history, taxonomy, and morphology of the causative organism. This paper will deal with the known hosts of the rust, our present knowledge of its specialized varieties, and with the comparative susceptibility of certain wheat varieties to *Puccinia glumarum tritici* Erikss. & Henn., as indicated by field and greenhouse experiments.

HOSTS

Eriksson (4), in his original report upon *Puccinia glumarum*, when it was separated from the now obsolete *Puccinia rubigo-vera* (DC.) Wint., named wheat, barley, rye, *Elymus arenarius*, and *Agropyron repens* as hosts for the new form. Saccardo (16, p. 380) lists the following hosts: *Brachypodium silvaticum*, *Bromus mollis*, *Calamagrostis epigeios*, *Hordeum vulgare*, *Secale cereale*, *Triticum caninum*, *T. compactum*, *T. dicoccum*, *T. descriptorum*, *T. distichon*, *T. durum*, *T. giganteum*, *T. polonicum*, *T. repens*. Hecke (7) reports the unpublished work of K. Barfus in which he lists *Dactylis glomerata* as an additional host.

¹ Accepted for publication May 2, 1923. The investigations upon which this paper is based were conducted cooperatively by the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, and the Oregon and Idaho Agricultural Experiment Stations.

² The writers wish to acknowledge with gratitude the hearty cooperation of Prof. G. R. Hyslop, Mr. Allen Clark, and Mr. D. E. Stephens in furnishing wheat varieties for this study, and to thank Mr. C. R. Erick, Mr. J. T. Breger, and Mr. J. C. Bell for their aid in taking notes, and Fred H. P. Hays, Dr. H. B. Humphrey, and Dr. A. G. Johnson for helpful suggestions during the progress of the work and in the preparation of this report. We also wish to express our appreciation for the valuable assistance given by A. S. Hitchcock and Mrs. Agnes Chase in the determination of the grasses used in the studies herein reported.

³ Reference is made by number (italic) to "Literature cited," p. 200-201.

Stripe rust has been found in the western part of the United States on wheat, barley, rye, spelt, and emmer in the field, and upon 33 wild grasses. The wild grass hosts found naturally infected include seven species of *Agropyron*: *A. spicatum* (Pursh) Scribn. & Smith, *A. cristatum* L. Gaertn., *A. dasystachyum* (Hook.) Scribn., *A. intermedium* (Host) Beauv., *A. violaceum* (Hornem.) Lange, *A. lanceolatum* Scribn. & Smith, eight species of *Bromus*: *B. marginatus* Nees, *B. pacificus* Shear, *B. stichoides* Trin., *B. carinatus* Hook. & Arn., *B. carinatus hookerianus* (Thurb.) Shear, *B. rubens* L., *B. brizaeformis* Fisch. & Mey., and *B. polyanthus* Scribn.; six species of *Elymus*: *E. canadensis* L., *E. condensatus* Presl, *E. glaucus* Buckl., *E. macounii* Vasey, *E. striatus* Willd., and *E. argutus* L.; six species of *Hordeum*: *H. jubatum* L., *H. gussoneanum* Parl., *H. murinum* L., *H. nodosum* L., *H. pusillum* Nutt., and *H. caespitosum* Scribn.; two species of *Hystrix*: *H. patula* Moench, and *H. californica* (Boland.) Kuntze; three species of *Sitanion*: *S. jubatum* J. G. Smith, *S. hystrix* (Nutt.) J. G. Smith, and *S. longifolium* J. G. Smith; one species of *Phalaris*, *P. paradoxa* L., and one wild species of *Triticum*, *T. argyle* Beauv.

The rust has been found on wheat in nearly all the western States, but has been reported on barley from only four districts, viz: Eastern Washington, eastern Oregon, western South Dakota, and central California. Only three collections have been made on rye, these being from northern Idaho, eastern Oregon, and western Oregon. The possible significance of the limited distribution of the rust on the last-named hosts will be discussed later.

The occurrence of stripe rust on *Bromus marginatus*, *Elymus canadensis*, *E. glaucus*, *Hordeum nodosum* and *H. jubatum* has been found to be quite general within the known geographic limits of the various grasses and of the parasite. *Hordeum murinum* was very generally infected in 1917 and in 1922 in the lower coast district of California, but has never been found so infected in other sections of the Pacific Coast where this host commonly occurs and where the rust has been present on other grasses. The collections on other hosts have been few in number and indicate that they are not as common hosts for the disease as the others already mentioned. In some cases, at least, they are more limited in their distribution.

As will be shown in a forthcoming paper of this series of studies,⁴ a number of collections of stripe rust had been made prior to May, 1915, when stripe rust was first recognized in the United States. These had been identified as several other rusts. Among these collections appear two hosts which have not been found naturally infected since that time. They are *Bromus carinatus hookerianus* (Thurb.) Shear, and *Sitanion longifolium* J. G. Smith.

The variety peculiar to wheat, *Puccinia glumarum tritici* Erikss. and Henn., has been found capable of infecting the following additional hosts when inoculations were made in the greenhouse: *Agropyron tenerum* Vasey, and *A. smithii* Rydb.; *Bromus hordeaceus* L., *B. inermis* Leyss., *B. comenstatatus* Schrad., *B. sterilis* L., *B. tectorum* L., *B. rigidus* Roth, and *B. ciliatus* L.; *Elymus australis* Scribn. and Ball, and *E. robustus* Scribn. and Smith. A detailed discussion of the methods used and the results obtained in connection with the above determinations will be given later under the discussion of specialized races of *P. glumarum*.

⁴In manuscript.

Since the completion of the foregoing studies, headquarters for the investigations on stripe rust have been transferred from Corvallis, Oreg., to Moscow, Idaho, and the research is now being carried on by the senior author and Mr. J. M. Raeder. Since the transfer, the following additional hosts for *Puccinia glumarum tritici* have been determined by greenhouse inoculation: *Agropyron tenerum longifolium* Scribn. and Smith., *A. aratum* (DC.) Roem. and Schult., *Bromus purgans latiglumis* (Scribn.) Shear, *B. lanuginosus* Poir., *B. erectus* Huds., *B. macrostachys* Desf., *B. rigidus* Roth, *B. frondosus* (Shear) Woot. and Standl., *B. richardsonii* Link., *B. adoensis* Hochst., *Hordeum maritimum* Roth, *H. bulbosum* L., *Phalaris canariensis* L., and *Silalion hystrix* (Nutt.) J. G. S. The grasses in this list, with those listed previously, comprise fifty-nine species of common wild grasses which are known to be hosts for stripe rust as it occurs in the United States. Thirty-three of these have been found naturally infected, and twenty-six of them determined by artificial inoculation with *P. glumarum tritici*. Doubtless other hosts will be added to this list as our knowledge of this rust becomes more complete.

SPECIALIZED VARIETIES

Eriksson (4) named five specialized varieties of *Puccinia glumarum*, based on inoculation experiments carried on by him. These were *P. glumarum tritici* on wheat, *P. glumarum hordei* on barley, *P. glumarum secalis* on rye, *P. glumarum elymi* on *Elymus arenarius* and *P. glumarum agropyri* on *A. repens*. He states that the varieties on wheat and barley appear to be sharply fixed (scharf fixiert); that is, he could not secure infection upon barley or rye with the variety *tritici*, or upon wheat or rye with the variety *hordei*. The variety *secalis* appeared to be less sharply fixed, since he secured slight infection upon wheat inoculated with this variety. He considered that he might have had a mixed culture in the latter case. Neither of the varieties on *Agropyron repens* and on *Elymus arenarius* would infect wheat, barley, or rye, nor was he able in either case to re-infect the original host.

It appears then that Eriksson had good evidence for establishing the varieties *P. glumarum tritici* and *P. glumarum hordei*, but there is some question as to the evidence in the case of the other three varieties.

In the field survey for stripe rust, conducted by the writers, an attempt has been made to record not only the name and location of infected hosts but also the name of other near-by grasses and cereals. It was thought that these notes might furnish valuable data regarding the spread of the rust from host to host in the field and also supplement the study on specialized varieties being conducted in the greenhouse.

As stated above, *Hordeum jubatum* and *Bromus marginatus* are two of the most common hosts for *P. glumarum* in the northwestern States. Wherever these two grasses have been found growing near each other, if one was infected, the other usually was infected also. With few exceptions, wherever infection was common on either of these two wild hosts, stripe rust could be found also on wheat if plants of a susceptible variety could be found growing near by. This also was true to a more limited extent of *Elymus glaucus*, *Hordeum nodosum*, *Elymus canadensis*, and *Elymus condensatus*, although these latter grasses are much more limited in their distribution and do not appear to be as common hosts for stripe rust as are the two first named.

In 1917, and again in 1922, *Hordeum murinum* was found to be one of the most common hosts for stripe rust along the Pacific Coast in southern California. Very seldom was any other host found infected, although other possible hosts often were growing in close proximity.

EXPERIMENTAL METHODS

The greenhouse experiments in the study of specialized varieties of *Puccinia glumarum*, as well as in the testing of wheat varieties for susceptibility to stripe rust, were carried on at Corvallis in a small wing of the greenhouse of the Oregon Agricultural Experiment Station. The methods used in greenhouse inoculations were, with certain modifications, like those employed by Stakman and Piemeisel (18) in their stem-rust studies. Every precaution was taken to guard against chance infections.

Seedlings were used with few exceptions, and were inoculated on the first or primary leaf. Plate 1, A and B, shows the method of preparing the seedlings for inoculation and the devices used for obtaining favorable conditions for infection. In every case the plants in a given pot were divided into two groups before any inoculations were made. This was done usually by pulling up or cutting close to the soil those in a line through the center of the pot. A piece of string was then laid on the soil between the two groups of seedlings. One half of these were inoculated and the other half left as control plants. In only one or two instances did any infection develop on the controls, and then only on a plant immediately adjacent to the inoculated ones. In such cases the results were not considered.

Inoculations were made by carefully transferring fresh urediniospores to the upper side of the leaf by means of a small scalpel. Melchers (19) found that he could obtain satisfactory infection on wheat with *Puccinia graminis tritici* E. & H. by inoculating the under side of the leaf. This did not prove to be the case with *Puccinia glumarum tritici*. Several trials were made by taking wheat plants of the same age and variety and inoculating part on one side of the leaf and part on the other. Only a very few infections resulted from the inoculations made on the under side, while nearly 100 per cent of those inoculated on the upper side of the leaf became infected.

At first, bell jars and battery jars were used for incubation chambers. Later, however, shallow tubs covered with a window sash were used to good advantage. After inoculation, the pots were placed in a tub containing about 2 inches of water, covered, and left in this moist chamber for 48 hours. They then were removed to the greenhouse bench. The various strains of the rust were kept in separate compartments in the greenhouse, and were isolated by means of partitions made of fine cheesecloth.

RESULTS

Inadequate greenhouse space made it impossible to work with a large number of collections of stripe rust. All of those studied proved to be *Puccinia glumarum tritici*. Each infected wheat readily, rye slightly, barley very slightly, if at all, and oats not at all. Table I shows the results of inoculations made on various varieties of barley and rye with urediniospores from wheat. As barley has been found heavily infected in the field several times, it appears that there must be a distinct special

host race which infects that host. Thus far, it has not been possible to obtain the race for experiment from barley.

Under "Character of Infection" the following five grades of infection have been used:

- 0—No uredinia; flecks and dead areas sometimes present; portions of leaves sometimes killed or discolored (Pl. 3 and 4).
- 1—Uredinia few or minute, generally surrounded by dead areas; portions of leaves sometimes killed or discolored (Pl. 5).
- 2—Uredinia normal in appearance, but few and scattered; discoloration of leaf tissues common (Pl. 6, A).
- 3—Uredinia normal, moderately abundant; little discoloration of leaf tissue (Pl. 6, B).
- 4—Uredinia normal and very abundant, appearing uniformly over surface of inoculated leaf; no discoloration in early stages of infection (Pl. 6, C).

"Br." in Table II, indicates that there was pronounced browning of the tissue around the border of the dead areas produced by the rust (see Pl. 3, A).

TABLE I.—Results obtained when barley and rye varieties were inoculated with uredinio-spores of stripe rust from wheat

Crop and variety.	Number of plants.		Character of infection.
	Inoculated.	Infected.	
Barley:			
Sandrel.....	49	0	0
O. A. C. Sel. No. 7.....	45	0	0
O. A. C. Sel. No. 8.....	36	0	0
Black Hull-less.....	48	1	2
Tennessee Winter.....	33	0	0
White Hull-less.....	63	0	0
Peruvian.....	48	0	0
Hannchen.....	34	2	2
Trebi.....	68	10	2
Rye:			
Abruzzi.....	43	6	3
Common.....	43	12	3

The results of various inoculations made with *Puccinia glumarum tritici* from several sources on various wild grasses and cereals to ascertain which were hosts for the rust are presented briefly in Table II. In some cases the results represent only one trial, while in other instances several experiments were made. Chul wheat was used in all cases.

TABLE II.—Results of inoculation of urediniospores of *Puccinia glumarum tritici* from different original and immediate hosts on numerous wild grasses and cereals.

Original host.	Immediate host.	Plant inoculated.	Number of experiments.		Number of plants.	
			Infection obtained.	No infection obtained.	Inoculated.	Infection obtained.
Wheat.....	Wheat.....	<i>Agropyron cristatum</i>	1	.....	4	3 3
Do.....	do.....	<i>Agropyron desertorum</i>	1	.....	30	28 4
Do.....	do.....	<i>Agropyron intermedium</i>	1	.....	18	12 4
Do.....	do.....	<i>Agropyron smithii</i>	1	2	45	5 1
Do.....	do.....	<i>Agropyron spicatum</i>	1	.....	2	2 4
Do.....	do.....	<i>Agropyron tenerum</i>	1	1	39	12 2
Do.....	do.....	<i>Bromus hordeaceus</i>	1	.....	25	2 2
Do.....	do.....	<i>Bromus inermis</i>	1	2	74	2 1
Do.....	do.....	<i>Bromus marginatus</i>	2	.....	42	33 4
Do.....	do.....	<i>Bromus polyanthus</i>	2	.....	20	15 4
Do.....	do.....	<i>Bromus secalinus</i>.....	.....	2	24	0 0
Do.....	do.....	<i>Dactylis glomerata</i>.....	.....	4	50	0 0
Do.....	do.....	<i>Elymus canadensis</i>	1	.....	14	14 4
Do.....	do.....	<i>Elymus glaucus</i>	1	.....	16	12 4
Do.....	do.....	<i>Elymus condensatus</i>	2	.....	28	20 4
Do.....	do.....	<i>Elymus virginicus</i>	1	.....	30	28 4
Do.....	do.....	<i>Hordeum gussoneanum</i>	1	.....	12	7 4
Do.....	do.....	<i>Hordeum jubatum</i>	3	.....	50	35 4
Do.....	do.....	<i>Hordeum nodosum</i>	2	.....	35	20 4
Do.....	do.....	<i>Hordeum pusillum</i>	1	.....	13	13 4
Do.....	do.....	<i>Hystrix hystrix</i>	1	.....	13	13 4
Do.....	do.....	<i>Sitonia jubatum</i>	1	.....	8	7 4
Do.....	do.....	Barley.....	2	12	235	13 2
Do.....	do.....	Oats.....	.....	4	50	0 0
Do.....	do.....	Rye.....	3	5	120	20 2
Do.....	<i>Bromus marginatus</i>	Wheat.....	3	.....	50	40 4
Do.....	<i>Elymus canadensis</i>	do.....	1	.....	9	9 4
Do.....	<i>Elymus glaucus</i>	do.....	1	.....	9	5 4
Do.....	<i>Sitonia jubatum</i>	do.....	1	.....	9	8 4
<i>Bromus marginatus</i>	Wheat.....	<i>Agropyron smithii</i>.....	.....	1	3	0 0
Do.....	do.....	<i>Arrhenatherum elatius</i>.....	.....	1	22	0 0
Do.....	do.....	<i>Beckmannia erucaeformis</i>.....	.....	1	10	0 0
Do.....	do.....	<i>Bromus carinatus</i>	1	1	26	1 10
Do.....	do.....	<i>Bromus ciliatus</i>	1	1	14	2 2
Do.....	do.....	<i>Bromus hordeaceus</i>	1	1	40	2 1
Do.....	do.....	<i>Bromus inermis</i>	1	1	20	4 10
Do.....	do.....	<i>Bromus japonicus</i>.....	.....	2	25	0 10
Do.....	do.....	<i>Bromus pratensis</i>.....	.....	1	30	2 0
Do.....	do.....	<i>Bromus secalinus</i>.....	.....	1	10	0 0
Do.....	do.....	<i>Bromus tectorum</i>.....	.....	1	25	0 0
Do.....	do.....	<i>Elymus australis</i>.....	.....	1	20	2 10
Do.....	do.....	<i>Elymus canadensis</i>.....	.....	1	14	5 4
Do.....	do.....	<i>Elymus glaucus</i>.....	.....	1	10	3 4
Do.....	do.....	<i>Festuca elatior</i>.....	.....	1	20	0 0
Do.....	do.....	Barley.....	.....	2	13	0 0
Do.....	do.....	Wheat.....	7	.....	140	114 4

TABLE II.—Results of inoculation of urediniospores of *Puccinia glumarum tritici* from different original and immediate hosts on numerous wild grasses and cereals—Cont'd.

Original host.	Immediate host.	Plant inoculated.	Number of experiments.		Number of plants.		Character of infection.
			Infection obtained.	No infection obtained.	Inoculated.	Infected.	
<i>Bromus marginatus</i> .	<i>Bromus marginatus</i> .	<i>Bromus marginatus</i> .	1	.....	10	8	4
	do.	<i>Bromus sterilis</i> .	1	.....	8	8	4
<i>Bromus glaucus</i> .	Wheat.	<i>Agropyron caninum</i>.	.....	1	12	0	0
	do.	<i>Agropyron repens</i>.	.....	1	10	0	0
Do.	do.	<i>Agropyron smithii</i>.	.....	1	13	0	0
Do.	do.	<i>Agropyron tenerum</i>.	.....	2	20	0	0 Br.
Do.	do.	do.	.....	1	5	0	0
Do.	do.	<i>Beckmannia erucaeformis</i>.	.....	1	11	0	0
Do.	do.	<i>Bromus carinatus</i>.	.....	1	30	0	0 Br.
Do.	do.	<i>Bromus ciliatus</i>.	.....	1	13	0	0 Br.
Do.	do.	<i>Bromus inermis</i>.	.....	2	30	0	0 Br.
Do.	do.	<i>Bromus marginatus</i> .	3	.....	42	36	4
Do.	do.	<i>Bromus polyanthus</i> .	1	.....	8	4	4
Do.	do.	<i>Bromus pratensis</i>.	.....	1	14	0	0 Br.
Do.	do.	<i>Bromus secalinus</i>.	.....	2	28	0	0
Do.	do.	do.	.....	1	10	0	0
Do.	do.	<i>Bromus sterilis</i> .	1	.....	7	7	3
Do.	do.	<i>Bromus vulgaris</i>.	.....	1	12	0	0 Br.
Do.	do.	<i>Elymus condensatus</i> .	1	.....	13	10	4
Do.	do.	do.	1	.....	8	4	3
Do.	do.	do.	1	.....	28	14	3
Do.	do.	<i>Elymus glaucus</i> .	5	.....	120	100	4
Do.	do.	<i>Elymus robustus</i> .	1	.....	4	1	4
Do.	do.	<i>Elymus striatus</i>.	.....	1	8	0	0
Do.	do.	<i>Festuca elatior</i>.	.....	1	15	0	0
Do.	do.	<i>Festuca pratensis</i>.	.....	1	10	0	0
Do.	do.	<i>Hordeum gussoncanum</i> .	1	.....	10	6	3
Do.	do.	<i>Hordeum murinum</i> .	2	1	32	10	1
Do.	do.	do.	2	2	62	8	2
Do.	do.	<i>Hordeum nodosum</i> .	2	.....	20	18	4
Do.	do.	<i>Sitanion jubatum</i> .	2	.....	15	14	4
Do.	do.	Barley.	.....	4	32	0	0
Do.	do.	do.	.....	1	20	0	0
Do.	do.	Emmer (Black Winter).	2	.....	35	30	4
Do.	do.	Oats.	.....	1	15	0	0
Do.	do.	Rye.	.....	1	15	0	0
Do.	do.	Wheat.	5	.....	125	110	4
<i>Hordeum jubatum</i> .	do.	<i>Agropyron repens</i>.	.....	1	9	0	0
	do.	<i>Bromus japonicus</i>.	.....	1	6	0	0 Br.
Do.	do.	<i>Bromus polyanthus</i> .	1	.....	10	10	4
Do.	do.	<i>Bromus sterilis</i> .	1	.....	6	3	1
Do.	do.	<i>Bromus tectorum</i> .	1	1	23	3	1
Do.	do.	<i>Bromus rigidus</i> .	1	.....	10	2	1 Br.
Do.	do.	<i>Elymus glaucus</i> .	1	.....	12	5	4
Do.	do.	<i>Hordeum murinum</i> .	1	2	20	3	1
Do.	do.	<i>Lolium temulentum</i>.	.....	1	13	0	0 Br.
<i>Hordeum nodosum</i> .	do.	<i>Bromus polyanthus</i> .	2	.....	22	19	4

TABLE II.—Results of inoculation of urediniospores of *Puccinia glumarum tritici* from different original and immediate hosts on numerous wild grasses and cereals—Cont'd.

Original host.	Immediate host.	Plant inoculated.	Number of experiments.		Number of plants.		
			Infection obtained.	No infection obtained.	Inoculated.	Infected.	Class. No.
<i>Hordeum nodosum</i> .	Wheat.....	<i>Sitanion jubatum</i>	2	.....	26	24	4
Do.....	do.....	Rye.....	.....	1	18	0	0
Do.....	do.....	Wheat.....	2	.....	42	30	4
Do.....	<i>Bromus polyanthus</i> .	<i>B. carinatus</i>	2	.....	46	0	12
Do.....	<i>Hordeum nodosum</i> .	<i>Elymus condensatus</i> .	1	.....	12	8	2
Do.....	do.....	<i>Bromus commutatus</i>.	.....	1	20	0	0
Do.....	do.....	<i>Hordeum nodosum</i>	1	.....	12	12	4
Do.....	do.....	<i>Dactylis glomerata</i>	5	.....	60	0	0

The list in Table II includes 48 species of wild grasses which have been shown to be hosts of *P. glumarum tritici*. It includes 19 species of *Bromus*, 11 species of *Agropyron*, 7 species of *Elymus*, and 1 species each of *Hystrix*, *Sitanion*, and *Phalaris*. Collections have been made in the field on 12 additional infected grass hosts, but it has not been possible to determine if they were infected with the race which goes to wheat. These 12 species include: *Agropyron inerme* (Scribn. and Sm.) Rydb., *A. dasystachyum* (Hook.) Scribn., *A. caninum*, *Bromus pacificus* Shear, *Bromus silchensis* Trin., *Bromus carinatus hookerianus* (Thurb.) Shear, *Bromus brizaeformis* Fisch. and Mey., *Hordeum caespitosum* Scribn., *Hystrix californica* (Boland.) Kuntze, *Elymus striatus* Willd., *Elymus macounii* Vasey, *E. triticoides* Buckl., *Phalaris paradoxa* L., *Sitanion hystrix* (Nutt.) J. G. Smith, *Sitanion longijolchum* J. G. Smith, and *Aeluropus cylindrica* Beauv.

Only one specialized variety apparently has been used in these inoculation experiments, and this appears to be *Puccinia glumarum tritici* Erikss. & Henn. There are some indications that at least one other variety is present in the United States. This probably is *Puccinia glumarum hordei* Erikss. & Henn., as indicated by the fact that barley has been found heavily infected in a few instances, while the race commonly found on wheat does not pass readily to barley. There also is evidence that the rust on *Hordeum murinum* may not be the variety commonly found on wheat. A discussion of these varieties is reserved for a later paper.

In only one case in Table II does there occur a difference of more than two in the grade of infection recorded when the same host was inoculated with the rust taken from the different hosts. When *Bromus sterilis* was inoculated with rust spores from *Hordeum jubatum* the infection was recorded as 1. When spores were taken from *Bromus marginatus* and from *Elymus glaucus* the result was a grade of 4 in each case. There are two possible explanations for these results. There may have been two strains of *Puccinia glumarum tritici* involved, or it is possible that there were two strains of *Bromus sterilis* used, as the seed came from

two different sources. During the course of this work there have been several indications that there may be strains of the specialized variety *Puccinia glumarum tritici*, the same as exist in *P. graminis tritici*, as shown by Stakman and Piemeisel (18). During the course of these studies evidence has accumulated indicating the possible existence of varieties or strains of various grasses which may react very differently to a given strain of the parasite. This phase of the question is under investigation.

SUSCEPTIBILITY OF WHEAT VARIETIES TO PUCCINIA GLUMARUM TRITICI

No attempt will be made here to review the very extensive literature upon the subject of rust resistance. Complete reviews of the subject from various angles have been made by Eriksson and Henning (5), Bullen (1, p. 40-44), Comes (3), Nilsson-Lihle (14), and, more recently, Henning (8). The study in Europe on the relative resistance of various wheats to *Puccinia glumarum* also has been extensive. As might have been foreseen, the results obtained have varied greatly, for the men engaged have worked under entirely different conditions, and undoubtedly with different strains of the varieties of wheat used as well as with different strains of the rust.

This paper summarizes the results obtained through study of a large number of varieties of wheat for resistance to *Puccinia glumarum tritici* as it occurs in western Oregon. The wheat varieties were obtained partly from the Office of Cereal Investigations and partly from the Department of Farm Crops of the Oregon Agricultural College. Every precaution has been taken to keep these varieties free from mixtures.

Both greenhouse and nursery studies were carried on at Corvallis, Oreg. In all, 337 varieties and strains of wheat were grown in the rust nursery. Only 163 of these are included in Table III. The remainder were grown in only one year and therefore are not included. Ninety-two varieties were studied under greenhouse conditions. Not all of the 163 varieties were sown in the nursery in each of the three seasons through which the experiments were extended. In 1918 only 72 varieties and strains were grown. In 1919 additional seed was obtained and 142 varieties and strains were grown. Still other varieties were added in 1920. Likewise, not all of the 92 varieties were grown in the greenhouse in any one season. Because of inadequate space and assistance it was impossible to study in the greenhouse all of the varieties that were used in the rust nursery.

NURSERY EXPERIMENTS

In the rust nursery the varieties were all sown in rod rows. In some cases replicated sowings were made; in other cases there was only one row of each variety. All varieties of which seed was available were sown in the fall regardless of whether they were of winter or spring habit. Under the climatic conditions prevailing at Corvallis it was found that spring varieties, when sown in the autumn, survived the winter in practically as good condition as the winter varieties. In the first two years such varieties as were known to be of spring habit and of which seed was available were sown in duplicate rows in the spring. In 1920 all varieties of which seed was available were sown again in duplicate rows in the

spring regardless of whether they were winter or spring wheats. Of course the winter varieties did not head when sown in the spring nursery, so that it was impossible to get notes on head infection.

The methods of making inoculations in order to induce an epiphytotic of stripe rust in the nursery were such as seemed to offer the best conditions possible for an abundant and widespread infection. Border rows of Chul, one of the most susceptible varieties of wheat, were sown around all of the plots. These border rows were inoculated both by spraying a suspension of urediniospores over their entire length and by hand inoculation of individual plants at intervals in them.

In addition to the border-row inoculations, one end of each variety row was sprayed with a spore decoction and individual plants in every row were hand inoculated. Hand inoculations were made by smearing spores on the leaves with a scalpel, spraying the plants with water, and covering the inoculated plants with inverted flower pots for a period of 48 hours. The quantity of infection on the border row served as a control, showing whether or not climatic and other conditions were favorable for abundant infection.

The results of the 3-year study of the effects of such inoculations on 163 varieties of common, club, poulard, durum, and Polish wheats, and emmer, spelt, and einkorn, when grown in the nursery, are shown in Tables III and IV.

The method used to indicate the quantity of infection recorded in Table IV needs a word of explanation. It seemed to the writers that the usual method of estimating the quantity of rust on cereals was not the best for accurately indicating the quantity of stripe rust present. It was found that varieties differed widely in the proportion of the plants in the row which showed infection, as well as in the quantity of rust on those plants which were rusted. In other words, there was much variation in the rapidity and extent of the spread of the rust on the different varieties.

Table III shows, for each variety, the proportion of the plants which were rusted at the Oregon Agricultural Experiment Station in the fall of 1917 and the spring of 1918, expressed in percentages, and the degree of rustiness of these infected plants, expressed in terms of a scale ranging from 1 to 10. The degree of infection refers to the proportion of plant surface covered with rust. This necessitates the recording of two numbers to indicate the comparative susceptibility of each variety. In order to reduce these figures to a single product which would express at a glance this comparative susceptibility, the following plan was devised. The product of the percentage of plants infected by the degree of infection would give in comparative terms the average infection of any given variety, with a possible maximum of 1,000, where 100 per cent of the plants in the row were infected with a maximum degree of 10. This method of computation has been used to indicate infection of the plants when in leaf and when heading. Infection data were taken when about 5 leaves were out, and again when the heads were well out of the boot.

As an example of the application of this method, take from Table III the data for Chul when grown as a winter wheat in 1917-18. The percentages of infected plants recorded for the first, second, and third replications are 80, 100, and 70, respectively, and the degrees of infection are 6, 6, and 3, respectively. The sum of the products of each per-

centage by the corresponding degree is 1,290. Dividing this sum by the number of replications, gives 430, which, therefore, is the average product representing the comparative susceptibility of Chul wheat, based on a possible maximum of 1,000 (Table IV).

In Table III, the percentage of plants infected and the degree of infection are shown for the 1917-18 season. The average susceptibility of each variety is shown in Table IV, not only for the first season, but for the seasons 1918-19 and 1919-20 as well.

Evidence of the varying susceptibility, even of strains within a variety, is shown in the case of the White Winter variety. In Table IV are listed five different C. I. numbers¹ of this variety. It will be noted that C. I. No. 5219 is somewhat susceptible, while three other strains are entirely immune, so far as those experiments show. The White Winter selection, C. I. No. 5222, which is quite susceptible, is also morphologically distinct from the other strains. These results emphasize the statement made by Vavilov (19) that workers should be careful to designate the exact botanical classification of host as well as parasite. Vavilov suggests that pure lines are desirable in studies of varietal susceptibility.

¹Accession numbers of the Office of Cereal Investigations.

TABLE III.—Data obtained on the percentages of plants infected and the degree of infection by *Puccinia glumarum*, *tritici* on varieties of wheat, durum, emmer, einkorn, and emmer at the fifth-leaf stage and at maturity in the fall of 1917 and the spring of 1918, at the Oregon Agricultural Experiment Station

COMMON WHEATS

Group and variety.	C. I. No.	Fall sown.			Spring sown.		
		5th-leaf stage.	Heading.		5th-leaf stage.	Heading.	
		Plants infected per cent.	Degree of infection.	Plants infected per cent.	Degree of infection.	Plants infected per cent.	Degree of infection.
Hard red spring:							
Redatta (Minn. 1148)	3207						
Cedar	4177						
Chal.	2406	80	6	05	2	60	1
		100	6	100	5	90	6
		70	3	85	4	75	7
Early Red Fife	4932	30	5	0	80	7	0
		30	5	0	0	0	0
Chirka (Chirka Spring)	1517	0	0	0	0	0	0
		0	0	0	100	8	0
		0	0	0	80	7	0
Haynes Bluestem	2874	0	0	0	100	0	0
		0	0	0	70	4	0
		0	0	0	40	6	0
Kinney	5197	0	0	0	15	4	0
		0	0	0	0	0	0
Kinney (Surprise)	5107	10	1	0	0	0	0
		50	1	0	0	0	0
		10	1	0	0	0	0
		60	1	0	0	0	0
Kopka	2203	0	0	0	100	8	0
		0	0	0	100	7	0
		0	0	0	100	0	0

Marquis.....	3641	3642	3643	3644	3645	3646	3647	3648	3649	3650	3651	3652	3653	3654	3655	3656	3657	3658	3659	3660	3661	3662	3663	3664	3665	3666	3667	3668	3669	3670	3671	3672	3673	3674	3675	3676	3677	3678	3679	3680	3681	3682	3683	3684	3685	3686	3687	3688	3689	3690	3691	3692	3693	3694	3695	3696	3697	3698	3699	3700	3701	3702	3703	3704	3705	3706	3707	3708	3709	3710	3711	3712	3713	3714	3715	3716	3717	3718	3719	3720	3721	3722	3723	3724	3725	3726	3727	3728	3729	3730	3731	3732	3733	3734	3735	3736	3737	3738	3739	3740	3741	3742	3743	3744	3745	3746	3747	3748	3749	3750	3751	3752	3753	3754	3755	3756	3757	3758	3759	3760	3761	3762	3763	3764	3765	3766	3767	3768	3769	3770	3771	3772	3773	3774	3775	3776	3777	3778	3779	3780	3781	3782	3783	3784	3785	3786	3787	3788	3789	3790	3791	3792	3793	3794	3795	3796	3797	3798	3799	3800	3801	3802	3803	3804	3805	3806	3807	3808	3809	3810	3811	3812	3813	3814	3815	3816	3817	3818	3819	3820	3821	3822	3823	3824	3825	3826	3827	3828	3829	3830	3831	3832	3833	3834	3835	3836	3837	3838	3839	3840	3841	3842	3843	3844	3845	3846	3847	3848	3849	3850	3851	3852	3853	3854	3855	3856	3857	3858	3859	3860	3861	3862	3863	3864	3865	3866	3867	3868	3869	3870	3871	3872	3873	3874	3875	3876	3877	3878	3879	3880	3881	3882	3883	3884	3885	3886	3887	3888	3889	3890	3891	3892	3893	3894	3895	3896	3897	3898	3899	3900	3901	3902	3903	3904	3905	3906	3907	3908	3909	3910	3911	3912	3913	3914	3915	3916	3917	3918	3919	3920	3921	3922	3923	3924	3925	3926	3927	3928	3929	3930	3931	3932	3933	3934	3935	3936	3937	3938	3939	3940	3941	3942	3943	3944	3945	3946	3947	3948	3949	3950	3951	3952	3953	3954	3955	3956	3957	3958	3959	3960	3961	3962	3963	3964	3965	3966	3967	3968	3969	3970	3971	3972	3973	3974	3975	3976	3977	3978	3979	3980	3981	3982	3983	3984	3985	3986	3987	3988	3989	3990	3991	3992	3993	3994	3995	3996	3997	3998	3999	4000																																																																																																																																																																																																																																																																																																																													
Pioneer.....	4324	4325	4326	4327	4328	4329	4330	4331	4332	4333	4334	4335	4336	4337	4338	4339	4340	4341	4342	4343	4344	4345	4346	4347	4348	4349	4350	4351	4352	4353	4354	4355	4356	4357	4358	4359	4360	4361	4362	4363	4364	4365	4366	4367	4368	4369	4370	4371	4372	4373	4374	4375	4376	4377	4378	4379	4380	4381	4382	4383	4384	4385	4386	4387	4388	4389	4390	4391	4392	4393	4394	4395	4396	4397	4398	4399	4400	4401	4402	4403	4404	4405	4406	4407	4408	4409	4410	4411	4412	4413	4414	4415	4416	4417	4418	4419	4420	4421	4422	4423	4424	4425	4426	4427	4428	4429	4430	4431	4432	4433	4434	4435	4436	4437	4438	4439	4440	4441	4442	4443	4444	4445	4446	4447	4448	4449	4450	4451	4452	4453	4454	4455	4456	4457	4458	4459	4460	4461	4462	4463	4464	4465	4466	4467	4468	4469	4470	4471	4472	4473	4474	4475	4476	4477	4478	4479	4480	4481	4482	4483	4484	4485	4486	4487	4488	4489	4490	4491	4492	4493	4494	4495	4496	4497	4498	4499	4500	4501	4502	4503	4504	4505	4506	4507	4508	4509	4510	4511	4512	4513	4514	4515	4516	4517	4518	4519	4520	4521	4522	4523	4524	4525	4526	4527	4528	4529	4530	4531	4532	4533	4534	4535	4536	4537	4538	4539	4540	4541	4542	4543	4544	4545	4546	4547	4548	4549	4550	4551	4552	4553	4554	4555	4556	4557	4558	4559	4560	4561	4562	4563	4564	4565	4566	4567	4568	4569	4570	4571	4572	4573	4574	4575	4576	4577	4578	4579	4580	4581	4582	4583	4584	4585	4586	4587	4588	4589	4590	4591	4592	4593	4594	4595	4596	4597	4598	4599	4600	4601	4602	4603	4604	4605	4606	4607	4608	4609	4610	4611	4612	4613	4614	4615	4616	4617	4618	4619	4620	4621	4622	4623	4624	4625	4626	4627	4628	4629	4630	4631	4632	4633	4634	4635	4636	4637	4638	4639	4640	4641	4642	4643	4644	4645	4646	4647	4648	4649	4650	4651	4652	4653	4654	4655	4656	4657	4658	4659	4660	4661	4662	4663	4664	4665	4666	4667	4668	4669	4670	4671	4672	4673	4674	4675	4676	4677	4678	4679	4680	4681	4682	4683	4684	4685	4686	4687	4688	4689	4690	4691	4692	4693	4694	4695	4696	4697	4698	4699	4700	4701	4702	4703	4704	4705	4706	4707	4708	4709	4710	4711	4712	4713	4714	4715	4716	4717	4718	4719	4720	4721	4722	4723	4724	4725	4726	4727	4728	4729	4730	4731	4732	4733	4734	4735	4736	4737	4738	4739	4740	4741	4742	4743	4744	4745	4746	4747	4748	4749	4750	4751	4752	4753	4754	4755	4756	4757	4758	4759	4760	4761	4762	4763	4764	4765	4766	4767	4768	4769	4770	4771	4772	4773	4774	4775	4776	4777	4778	4779	4780	4781	4782	4783	4784	4785	4786	4787	4788	4789	4790	4791	4792	4793	4794	4795	4796	4797	4798	4799	4800	4801	4802	4803	4804	4805	4806	4807	4808	4809	4810	4811	4812	4813	4814	4815	4816	4817	4818	4819	4820	4821	4822	4823	4824	4825	4826	4827	4828	4829	4830	4831	4832	4833	4834	4835	4836	4837	4838	4839	4840	4841	4842	4843	4844	4845	4846	4847	4848	4849	4850	4851	4852	4853	4854	4855	4856	4857	4858	4859	4860	4861	4862	4863	4864	4865	4866	4867	4868	4869	4870	4871	4872	4873	4874	4875	4876	4877	4878	4879	4880	4881	4882	4883	4884	4885	4886	4887	4888	4889	4890	4891	4892	4893	4894	4895	4896	4897	4898	4899	4900	4901	4902	4903	4904	4905	4906	4907	4908	4909	4910	4911	4912	4913	4914	4915	4916	4917	4918	4919	4920	4921	4922	4923	4924	4925	4926	4927	4928	4929	4930	4931	4932	4933	4934	4935	4936	4937	4938	4939	4940	4941	4942	4943	4944	4945	4946	4947	4948	4949	4950	4951	4952	4953	4954	4955	4956	4957	4958	4959	4960	4961	4962	4963	4964	4965	4966	4967	4968	4969	4970	4971	4972	4973	4974	4975	4976	4977	4978	4979	4980	4981	4982	4983	4984	4985	4986	4987	4988	4989	4990	4991	4992	4993	4994	4995	4996	4997	4998	4999	5000
Preston.....	3681	3682	3683	3684	3685	3686	3687	3688	3689	3690	3691	3692	3693	3694	3695	3696	3697	3698	3699	3700	3701	3702	3703	3704	3705	3706	3707	3708	3709	3710	3711	3712	3713	3714	3715	3716	3717	3718	3719	3720	3721	3722	3723	3724	3725	3726	3727	3728	3729	3730	3731	3732	3733	3734	3735	3736	3737	3738	3739	3740	3741	3742	3743	3744	3745	3746	3747	3748	3749	3750	3751	3752	3753	3754	3755	3756	3757	3758	3759	3760	3761	3762	3763	3764	3765	3766	3767	3768	3769	3770	3771	3772	3773	3774	3775	3776	3777	3778	3779	3780	3781	3782	3783	3784	3785	3786	3787	3788	3789	3790	3791	3792	3793	3794	3795	3796	3797	3798	3799	3800	3801	3802	3803	3804	3805	3806	3807	3808	3809	3810	3811	3812	3813	3814	3815	3816	3817	3818	3819	3820	3821	3822	3823	3824	3825	3826	3827	3828	3829	3830	3831	3832	3833	3834	3835	3836	3837	3838	3839	3840	3841	3842	3843	3844	3845	3846	3847	3848	3849	3850	3851	3852	3853	3854	3855	3856	3857	3858	3859	3860	3861	3862	3863	3864	3865	3866	3867	3868	3869	3870	3871	3872	3873	3874	3875	3876	3877	3878	3879	3880	3881	3882	3883	3884	3885	3886	3887	3888	3889	3890	3891	3892	3893	3894	3895	3896	3897	3898	3899	3900	3901	3902	3903	3904	3905	3906	3907	3908	3909	3910	3911	3912	3913	3914	3915	3916	3917	3918	3919	3920	3921	3922	3923	3924	3925	3926	3927	3928	3929	3930	3931	3932	3933	3934	3935	3936	3937	3938	3939	3940	3941	3942	3943	3944	3945	3946	3947	3948	3949	3950	3951	3952	3953	3954	3955	3956	3957	3958	3959	3960	3961	3962	3963	3964	3965	3966	3967	3968	3969	3970	3971	3972	3973	3974	3975	3976	3977	3978	3979	3980	3981	3982	3983	3984	3985	3986	3987	3988	3989	3990	3991	3992	3993	3994	3995	3996	3997	3998	3999	4000																																																																																																																																																																																																																																																																																																																																																																					
Hard red winter:																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					

TABLE III.—Data obtained on the percentage of plants infected and the degree of infection by *Puccinia glumarum tritici* on varieties of wheat, emmer, spelt, and einkorn at the fifth-leaf stage and at maturity in the fall of 1917 and the spring of 1918, at the Oregon Agricultural Experiment Station—Continued

Group and variety.	C. I. No.	Fall sown.				Spring sown.			
		5th-leaf stage.		Heading.		5th-leaf stage.		Heading.	
		Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.
White:									
Baart (Early Baart).....	1697	50	2	80	3	100	8	0	0
		80	6	90	4	100	7	0	0
Challenge (Webbs Challenge White).....	4683	20	3	15	2	100	8	0	0
		0	0	0	0	0	0	0	0
Dicklow.....	4758	0	0	0	0	10	2	0	0
		0	0	0	0	0	0	0	0
Eaton.....	4682	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0
Federation.....	4734	20	3	15	2	90	7	0	0
		10	3	0	0	75	7	0	0
Florence.....	4270	50	3	0	0	100	4	0	0
		0	0	0	0	80	7	0	0
Foley.....	5253	0	0	0	0	20	2	0	0
		50	3	0	0	0	0	0	0
Goldsmith (American Farmer).....	4016	90	3	0	0	0	0	0	0
		10	3	0	0	0	0	0	0

<i>Gelber Winter (Fortyfold) (Wash. 1913)</i>									
4608	Jim Buck	100	0	0	0	0	0	0	0
5231	Pacific Bluestem	100	0	0	0	0	0	0	0
5868	Rink	100	0	0	0	0	0	0	0
4668	Royalton (Minn. 1037)	100	0	0	0	0	0	0	0
3936	Senora	100	0	0	0	0	0	0	0
2495	Tahmaka	100	0	0	0	0	0	0	0
4684	White Winter	100	0	0	0	0	0	0	0
4193	Wilhelmina	100	0	0	0	0	0	0	0
4690	Miscellaneous: Hansia Broach	100	0	0	0	0	0	0	0
4696	Popatia Nadiad	100	0	0	0	0	0	0	0
4564	Tigharia	100	0	0	0	0	0	0	0
5607	Western Sweepstakes	100	0	0	0	0	0	0	0

TABLE III.—Data obtained on the percentage of plants infected and the degree of infection by *Puccinia glumarum tritici* on varieties of wheat, emmer, speltz, and ankara at the fifth-leaf stage and at maturity in the fall of 1917 and the spring of 1918, at the Oregon Agricultural Experiment Station—Continued

Group and variety.	C. I. No.	Fall sown.				Spring sown.			
		5th-leaf stage.		Heading.		5th-leaf stage.		Heading.	
		Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.
Dale (Dale Gloria).....	4231	70	5	15	1	100	8	.....	.....
Hybrid 128.....	4512	60	3	5	2	80	9	0	0
Hybrid 143.....	4160	5	2	0	0	95	.....	0	.....
Little Club.....	4219	0	0	0	0	.....	.....	.....	.....
Salt Lake Club.....	3018	40	5	10	1	.....	.....	.....	.....
		25	4	10	0	.....	.....	.....	.....
		60	3	3	1	.....	.....	.....	.....
		80	3	15	2	.....	.....	.....	.....
		80	4	60	2	.....	.....	.....	.....
		75	4	60	3	.....	.....	.....	.....
POULARD WHEAT									
Titanic.....	5535	0	0	0	0	.....	.....	.....	.....
		10	0	0	0	.....	.....	.....	.....

TABLE III.—Data obtained on the percentage of plants infected and the degree of infection by *Puccinia glumarum tritici* on varieties of wheat, emmer, spelt, and einkorn at the fifth-leaf stage and at maturity in the fall of 1917 and the spring of 1918, at the Oregon Agricultural Experiment Station—Continued

SPELT

Group and variety.	C. I. No.	Fall sown.				Spring sown.			
		5th-leaf stage.		Heading.		5th-leaf stage.		Heading.	
		Plants infected per cent.	Degree of infection.	Plants infected per cent.	Degree of infection.	Plants infected per cent.	Degree of infection.	Plants infected per cent.	Degree of infection.
Red Winter	1772	0	0	0	0	.....	.....	.....	.....
POLISH WHEAT									
Polish	5524	.....	.....	.....	.....	50	0	0	0
						50	8	0	0
						50	7	0	0
EINKORN									
Einkorn	2433	.....	.....	.....	.....	0	0	0	0

TABLE 15. Data obtained on the susceptibility of varieties of wheat, summer, stock, and unknown to infection by *Puccinia glumarum* tested as determined by records taken when the plants grown in the variety were developing the 5th leaf and when they were heading, in one or more of the three years from 1918 to 1920, inclusive, at the Oregon Agricultural Experiment Station, Corvallis, Oreg.

COMMON WHEATS													
Varietal susceptibility.													
Group and variety.	C. I. No.	1917-1918				1918-1919				1919-1920			
		Fall sown.		Spring sown.		Fall sown.		Spring sown.		Fall sown.		Spring sown.	
		5-leaf stage.	Head- ing.	5-leaf stage.	Head- ing.	5-leaf stage.	Head- ing.	5-leaf stage.	Head- ing.	5-leaf stage.	Head- ing.	5-leaf stage.	Head- ing.
Hard red spring:													
Barietta (Minn. 1148).....	3207			2	0	0	0						
Qedar.....	4117			360	0	0	0						
Chul (Alturas, Calif.).....	2227					293	594			0	0	0	0
Chul.....	2227					133	792			0	0	0	0
Chul (Yantagbay).....	2404					135	700			0	0	0	0
Chul.....	2405	430	495	572	T.	830	792	0	135	0	0	0	0
Early Red Pile.....	4932	133	0			0	0	0	0	0	0	0	0
Ghirka (Ghirka Spring).....	1517			713	0	0	15	0	0	0	0	0	0
Haynes Bluestem.....	2674	0	0	193	0	0	0	3	0	0	0	0	0
Humpback.....	3660					35	0	0	0	0	0	0	0
Huron.....	3315												
Kinney.....	5107	0	0			T	0	0	0	0	0	0	0
Kinney (Surprise).....	5107	33	0			20	20	0	0	0	0	0	0
Koola.....	2293	367	7	687	0	60	60	425	0	1	0	80	0
Marquis.....	3641	0	0	467	0	5	5	1	0	0	0	250	0
Marquis (Minn. 1236).....	3641					T.	0			0	0	1	0
Pioneer.....	4324	7	T.	220	0	0	0	0	1	0	0	T.	0
Preston.....	2058					0	0	0	0	0	0	T.	0
Preston (Minn. 924).....	3681	33	0	117	0	0	0	0	1	0	0	0	0

COMMON WHEATS

TABLE IV.—Data obtained on the susceptibility of varieties of wheat, emmer, spelt, and einkorn to infection by *Puccinia glumarum tritici* as determined by records taken when the plants, grown in the nursery, were developing the fifth leaf and when they were heading, in one or more of the three years from 1918 to 1920, inclusive, at the Oregon Agricultural Experiment Station, Corvallis, Oreg.—Continued

COMMON WHEATS—continued													
Varietal susceptibility.													
Group and variety.		1917-1918				1918-1919				1919-1920			
		Fall sown.		Spring sown.		Fall sown.		Spring sown.		Fall sown.		Spring sown.	
		Head- ing.	Leaf stage.	Head- ing.	Leaf stage.	Head- ing.	Leaf stage.	Head- ing.	Leaf stage.	Head- ing.	Leaf stage.	Head- ing.	Leaf stage.
Hard red winter:													
Kanred.....	5146	o	o	540	o	o	o	o	o	o	o	75	o
Kharkof.....	2193	o	o			o	o	o	o	o	o	50	o
P-1066 (Kansas).....	5879					8	o	30	o	o	o	140	o
P-1068 (Kansas).....	5880					o	o	o	o	o	o	90	o
Turkey.....	1558	o	o			100	10			o	o	5	o
Soft red winter:													
Banner Berkeley.....	3406	o	o	o	o	25	o	50	o	o	o	25	o
Puleaster.....	3416	o	o	o	o	35	o	160	o	o	o	100	o
Fultz.....	3397	o	o			315	285			180	o	800	o
Gipsy (Economy).....	5793											T	o
Golden Cross.....	5186	2	1	o	o	63	500			o	o	700	o
Harvest Queen.....	4876	283	o			681	250			T	o	100	o
Illini Chief.....	5314	T	3			78	16	160	o	o	o	100	o
Jones Life.....	3452					471	100			1	o	125	o
Jones Life.....	4168					50	50	210	o	o	o	100	o
Jones Life (Super).....	5413					584	55			o	o	100	o
Jones Life.....	5413					584	55			o	o	100	o

COMMON WHEATS—continued

[illegible]

TABLE IV.—Data obtained on the susceptibility of varieties of wheat, emmer, speltz, and einkorn to infection by *Puccinia glumarum tritici* as determined by 1918 tests when the plants, grown in the nursery, were developing the fifth leaf and when they were heading, in one or more of the three years from 1908 to 1920, inclusive, at the Oregon Agricultural Experiment Station, Corvallis, Oreg.—Continued

Group and variety.		C. I. No.	Varietal susceptibility.										
			1917-1918			1918-1919			1919-1920				
			Fall sown.	Spring sown.	Fall sown.	Spring sown.	Fall sown.	Spring sown.	Fall sown.	Spring sown.	Fall sown.	Spring sown.	
			Head- mg.	Head- mg.	Head- mg.	Head- mg.	Head- mg.	Head- mg.	Head- mg.	Head- mg.	Head- mg.	Head- mg.	Head- mg.
White-Continued.													
Satisfaction (Smith's Rustproof)		3588											
Sonora		3630											
Do.		4293											
Do.		4501											
Talimka		4685	313	787	T.	289	490	136	150	T.	200	95	
White Winter		4744	0										
Do.		5219	0			33	5			T.	200	0	
Do.		5224											
Do.		5225											
Do.		5226				206	360			5	0	0	
Do.		5227											
Do.		4193	40	0		0	T.						
White Winter selection.		5409											
Willhelmina.													
Winter Bluestem.													
Miscellaneous:													
Hansia Branch.		4690	800	533	852	83	750	300	300	60	150	50	
Turkey x Chul (F ₃ , No. 1)							900	700		T.	0	480	
Do. (F ₃ , No. 2)							275	195		0	0	350	
Do. (F ₃ , No. 3)							35	140		0	0	450	
Do. (F ₃ , No. 3)							35	140		0	0	450	
Little Bluestem		6719	867	557	100	250	900	600	600	250	T.	800	100
Popoata Nudial		4606					758	100		0	0	0	
Ygharia		4504			707	53							
Trinamica		5003											

TABLE IV.—Data obtained on the susceptibility of varieties of wheat, emmer, spelt, and einkorn to infection by *Puccinia glumarum tritici* as determined by records taken when the plants, grown in the nursery, were developing the fifth leaf and when they were heading, in one or more of the three years from 1918 to 1920, inclusive, at the Oregon Agricultural Experiment Station, Corvallis, Oreg.—Continued

[illegible]

ADDITIONAL FIELD DATA

In addition to the information tabulated above on susceptibility of varieties in the rust nursery at Corvallis, Oreg., during the three seasons, many valuable field notes were recorded at various times and places where rust infection had developed under natural conditions.

At the Sherman County Branch Station, at Moro, Oreg., where extensive sowings of wheat varieties are made each year, there was a severe outbreak of stripe rust in the spring of 1919. This afforded an excellent opportunity to obtain data on the comparative susceptibility of some of the leading varieties of wheat grown at that station in 1919. The following table shows the ratings of these varieties, using the system of grading explained for Tables III and IV. The notes, taken just before the plants headed, are recorded in Table V.

TABLE V.—Data showing the susceptibility of commercial wheat varieties to infection by stripe rust at the Sherman County Branch Station, Moro, Oreg., in 1919

Variety.	C. I. No.	Varietal susceptibility.
Turkey.....	1558	425
Do.....	1571	410
Do.....	1756	325
Do.....	2998	415
Turkey (Local).....	4429	390
Kinrod.....	5146	525
Argentine.....	1560	560
Crane.....	1437	510
Alberta Red.....	2979	675
Belogima.....	2239	710
Theris.....	1561	105
Nebraska No. 28.....	5147	355
Kharok.....	5540	250
James Fife.....	6177	855
Hybrid 128.....	4512	630
Guldein (Fortyfold).....	4156	635

During the season of 1919 notes were taken also on the stripe rust occurring on a number of wheat varieties growing at Moscow in the plots of the agronomy department of the University of Idaho. The notes were taken on June 20, when the grain was mostly headed. Apparently the rust was just beginning to appear at that time and, as no opportunity presented itself to inspect this grain again, it is not known that the figures in Table VI represent the maximum rust infection which appeared on these plots during that season. At any rate, they give some indication of the most susceptible varieties.

TABLE VI.—Data showing susceptibility of wheat varieties to stripe rust after heads first appeared, when grown in plots at the University of Idaho, Moscow, in 1919

Variety.	C. I. No.	Varietal susceptibility
Prohibition.....	4068	0
Challenge (Webbs Challenge White).....	4683	0
Rink.....	3868	0
White Winter.....	4684	0
Defiance.....	4354	0
Pacific Bluestem.....	3010	0
Kinney.....	5189	0
Red Russian.....	4590	0
Fultz.....	3416	0
Marquis.....	3641	0
Dawson (Dawson Goldenchaff).....	4180	Trace
Early Arcadia.....	4220	0
Red Wave.....	3590	0
Poolc.....	3488	0
Poolc (Harvest King).....	4894	400
Jones Fife.....	3452	400
Haynes Bluestem.....	2874	0
Sonora.....	4293	0
Baart (Early Baart).....	1697	Trace
Stoner.....	2980	0
Golden Cross.....	5180	0
Kharkof.....	1442	0
Preston.....	2958	0
Hybrid 63.....	4157	Trace

During the summer of 1920 there was an outbreak of stripe rust in the wheat classification nursery at Corvallis, Oreg. Table VII shows the comparative susceptibility of some of the varieties as indicated by the rust infection which appeared on them after the plants were all headed.

TABLE VII.—Data showing susceptibility of wheat varieties to stripe rust when grown in the wheat classification nursery at Corvallis, Oreg., in 1920

COMMON WHEATS		
Group and variety.	C. I. No.	Varietal susceptibility
Hard red spring:		
Chul.....	2227	50
Early Red Fife.....	4932	0
Haynes Bluestem.....	2874	0
Humpback.....	3690	0
Huston.....	5208	0
Kinney.....	5189	0
Marquis.....	3641	0
Pioneer.....	4324	0
Prelude.....	4323	400
Preston.....	3328	0
Preston (Velvet Chaff).....	3318	0
Hard red winter:		
Alton (Chirka Winter).....	1438	0
Beloglina.....	1667	0
Kanred.....	5146	0
Kharkof.....	1442	0
Turkey.....	1558	0

TABLE VII.—Data showing susceptibility of wheat varieties to stripe rust when grown in the wheat classification nursery at Corvallis, Oreg., in 1920—Continued

COMMON WHEATS—continued

Group and variety.	C. I. No.	Varietal susceptibility.
Soft red winter:		
Climax (Jones Climax).....	6203	275
Correll.....	3326	70
Correll (Golden Chaff).....	5578	00
Diamond Grit.....	3385	100
Fulcrum.....	3406	50
Fultz.....	3410	150
Gipsy (Defiance).....	5395	0
Golden Cross.....	5180	T.
Grand prize.....	4876	400
Harold.....	6005	600
Harvest Queen.....	5314	0
Harvest Queen (Red Cross).....	4882	0
Illini Chief.....	5400	0
Jones Fife.....	4468	250
Jones Fife (Super).....	5544	600
Jones Longberry.....	5339	0
Leap.....	4823	0
Lufthouse.....	3275	0
Mealy.....	3358	20
Nebraska No. 28.....	5147	100
New Columbia.....	5916	20
Pool.....	3188	900
Pool (Harvest King).....	5680	570
Prosperity (American Bronze).....	5380	125
Red Clawson (Early Red Clawson).....	3393	550
Red May.....	5336	20
Red May (Early Harvest).....	4334	20
Red May (Early Ripe).....	3394	150
Red May (Michigan Amber).....	1909	0
Red May (Enterprise).....	4854	T.
Red Russian.....	4509	0
Red Wave.....	3500	250
Rural New Yorker No. 6.....	5921	0
Rural New Yorker No. 57.....	3516	50
Squarehead.....	5234	0
Stoner.....	2980	0
Triplet.....	5408	0
Zimmerman.....	2927	0
White:		
Bearded Winter Fife.....	4204	100
Bobs.....	4990	T.
Challenge (Webbs Challenge White).....	4683	0
Dawson Goldenchaff.....	3347	50
Defiance.....	4347	5
Dicklow.....	3063	0
Early Arcadia.....	3199	125
Eaton.....	5682	0
Foisy.....	5247	0
Genesee Giant.....	1744	300
Goldcoin.....	2996	50
Gypsum (Colorado Special).....	4762	0
Hard Federation.....	4980	0
Jumbuck.....	4608	0
Kofod.....	4337	0
New Zealand.....	6011	5
Oatka Chief.....	3481	300

TABLE VII.—Data showing susceptibility of wheat varieties to stripe rust when grown in the wheat classification nursery at Corvallis, Oreg., in 1920—Continued

COMMON WHEATS—continued		
Group and variety.	C. I. No.	Yield, bushels per acre
White—Continued.		
Pacific Bluestem.....	4067	
Prohibition.....	4068	
Rink.....	5868	
Satisfaction.....	5938	
Satisfaction (Smith's Rustproof).....	5588	11
Seneca Chief.....	5575	
Silvercoin.....	6013	11
Sonora.....	3030	
Sunset.....	6253	21
Surprise (White Russian).....	5277	
Talimka.....	2495	11
White Australian.....	3019	0
White Federation.....	4981	11
White Winter.....	5219	0
CLUB WHEATS		
Big Club.....	4257	0
Bluechaff.....	5750	100
Brown Glory.....	4240	100
Coppel.....	3688	100
Dale (Dale Gloria).....	4155	400
Hybrid 60.....	5024	0
Hybrid 108.....	5025	100
Hybrid 123.....	4511	117
Hybrid 128.....	4512	200
Jenkin.....	5177	400
Little Club.....	4066	100
Mayview.....	5874	0
Redchaff.....	4241	100
MISCELLANEOUS WHEATS		
Alaska (poulard).....	5988	0
Arnautka (durum).....	1494	0
Einkorn.....	2433	0
Khapli emmer.....	4913	0
Kubanka (durum).....	1440	0
Mindum (durum).....	5296	0
Red Winter spelt.....	1772	0
Vernal (White Spring) emmer.....	1524	0
White Spring spelt.....	2668	0

GREENHOUSE EXPERIMENTS

The greenhouse studies on susceptibility of grain varieties to stripe rust were carried out in a wing of the greenhouse at the Oregon Agricultural Experiment Station, at Corvallis. The methods used were the same as previously outlined in the investigation of specialized races.

The results of the inoculations made in the greenhouse during the three seasons, 1917-18, 1918-19, and 1919-20, using 92 different varieties and strains of wheat, are embodied in Table VIII. The method used in computing data has already been explained in connection with Tables III and IV.

TABLE VIII.—Data on susceptibility of varieties of wheat, emmer, spelt, and einkorn to stripe rust, including the number of separate experiments made each season and in all seasons, the number of plants inoculated and the number infected in each season and in all three seasons, and the actual and average degree of infection, when the plants were grown in the greenhouses at Corvallis, Oreg., in the three seasons, 1917-18, 1918-19, and 1919-20

COMMON WHEATS

Group and variety.	C. I. No.	1917-18				1918-19				1919-20				Totals.			
		Number of—			Character of infection.	Number of—			Character of infection.	Number of—			Character of infection.	Number of—			Character of infection.
		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.	
Hard red spring:																	
Barietta (Minn. 1148).....	3297																
Cedar.....	4117																
Chul.....	2227-1																
Chul (Yantagbay).....	2404																
Chul.....	2406																
Dakota No. 5.....		1	12	10	4	9	187	98	4	26	240	152	4	36	439	260	4
Dakota No. 1.....		1	15	0										1	15	0	0
Dakota No. 2.....			20	0										1	20	0	0
Ghirka (Ghirka Spring).....	1517													1	20	0	0
Haynes Bluestem.....	2874													1	20	0	0
Kinney.....	5197													1	20	0	0
Do.....	5197													1	20	0	0
Koola.....	2203													1	20	0	0
Marquis.....	3641													1	20	0	0
Pioneer.....	4234													1	20	0	0
Pioneer.....	3681													1	20	0	0
Red Bille.....	4932													1	20	0	0
Hard red winter:																	
Kanred.....	5146	2	33	33	4	9	158	47	4	3	50	17	3	14	241	97	14
Kharkef.....	2103					1	20	10	2	2	20	7	1	1	20	17	3

[illegible]

TABLE VIII.—Data on susceptibility of various corn, sorghum, millet, and sunflower to stripe rust, including the number of separate experiments made each season and in all seasons; the number of plants tested and the number infected; and the average degree of infection, and the average and maximum degree of infection, under all circumstances, and the general and average degree of infection, when the plants were grown in the greenhouse at Corvallis, Oreg., in the three seasons, 1917-18, 1918-19, and 1919-20.

Continued

Group and variety.	C. I. No.	1917-18				1918-19				1919-20				Totals.			
		Number of—		Character of infec- tion.	Number of—		Character of infec- tion.	Number of—		Character of infec- tion.	Number of—		Character of infec- tion.				
		Experiments.	Plants in- volved.		Plants in- volved.	Experiments.		Plants in- volved.	Plants in- volved.		Experiments.	Plants in- volved.					
White—Continued.																	
Pacific Blue st.	5231																
Rink	5865																
Royalton (Minn. 1037)	4968	1	8	1	1												
Sonora.	3056	1	68	4	1	6	42	11	1	3	30	2	1	10	140	17	
Do.	4203																
Do.	4501																
Tulimka.	2495					5	79	62	4	35	983	451	4	41	1,697	540	
White Wipter.	4884	1	35	27	4					1	10	0	0	1	10	0	
Do.	4884									2	23	0	0	2	23	0	
Withelmia.	5432									3	34	0	0	4	47	0	
Withelmia.	4193					1	13	0	0	3				1	10	4	
Miscellaneous:																	
Black Persian.	2442	1	10	4	3									2	55	40	
Chul x Turkey						2	55	40	4					3	39	22	
Hansia Broach.	4600													4	101	51	
Popatia Nadiad.	4606	1	14	14	4	7	76	35	4	1	11	2	4	0	101	51	
Western Sweepstakes.	5667					1	23	21	4	2	20	2	5	43	23	34	

THE UNIVERSITY OF CHICAGO

[illegible]

POULARD WHEAT

Titanic.....	5535	1	13	5	0	2	20	4	2	3	33	9	0-2
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DURUM WHEATS

[illegible]

LEMMER

[illegible]

TABLE VIII.—Data on susceptibility of varieties of wheat, summer spelt, and einkorn to stripe rust, including the number of separate experiments made each season and in all seasons, the number of plants inoculated and the number infected in each season and in all three seasons, and the annual and average degree of infection, when the plants were grown in the greenhouse at Corvallis, Oreg., in the three seasons, 1917-18, 1918-19, and 1919-20—Continued

SPRUIT														
Group and variety.	C. L. No.	1917-18			1918-19			1919-20			Totals.			Character of infection.
		Number of—			Number of—			Number of—			Number of—			
		Experiments.	Plants inoculated.	Plants infected.	Experiments.	Plants inoculated.	Plants infected.	Experiments.	Plants inoculated.	Plants infected.	Experiments.	Plants inoculated.	Plants infected.	
Red Winter	1772	1	30	1							1	30	1	1
EINKORN														
Einkorn	2433	1	20	0							1	20	0	1
Do.	2973	1	24	20							1	24	20	1

EINKORN

NURSERY AND GREENHOUSE RESULTS COMPARED

Table IX presents a comparison of the results obtained in both the nursery and greenhouse with certain varieties which have proved very resistant in all these trials. No varieties are listed unless they were grown three seasons in the nursery and tested for resistance there.

TABLE IX.—Data showing summarized results of nursery and greenhouse experiments on susceptibility of wheat varieties to infection by *P. glumarum tritici*

Variety.	C. I. No.	Nursery.		Greenhouse.	
		Number of experiments.	Average susceptibility.	Number of experiments.	Character of infection.
Burlington	3207	4	0.5	3	0
Dicklow	4758	8	12	5	0
Fossy	5253	6	17	2	2
Hickom	2433	4	0	1	0
Holtz	3410	5	14	1	0
Harvest Queen	5314	4	1	2	0
Haynes Bluestem	2874	6	33	5	1-2
Kharkof	2193	5	10	3	2-3
Kinney	5197	6	Trace.	1	0
Preston	3081	10	15	4	0
Wilhelmina	4193	6	0	4	0
Early Red Fife	4932	6	22	3	0
Red Russian	4509	6	4	2	0
Red Winter spelt	1772	5	0	1	1
Rink	5868	6	Trace.	5	2
Rocalton	4968	6	0	1	1
Smora	3036	6	4	10	1
Challenge (Webbs Challenge White)	4683	6	Trace.		
White Winter	4684	6	Trace.	1	0

As shown by Tables III to IX, there has been a marked difference in susceptibility to stripe rust in the different varieties of wheat. Further study doubtless will show whether there are strains of the rust which are able to attack some of these varieties which have proved resistant to the strains which have been under observation. The difference in susceptibility to stripe rust in the various varieties of wheat which have been studied seems to be much more marked than in the case of either stem rust or leaf rust.

Various European workers have referred to this very marked difference in susceptibility to *P. glumarum* as it appears in Europe. Henning (8) states in this connection, "The economic importance of the yellow rust has recently, in our country (Sweden), been considered rather inferior, since we, in the latter part of the nineteenth century, have demonstrated that the different varieties of wheat show a very unlike susceptibility to this disease; moreover, we have succeeded in producing varieties, by means of crossing, which possess a marked power of resistance toward yellow rust. However, we have learned recently that this power of resistance is quite variable, so that we must give some further attention to this kind of rust."

Comparatively few of the different varieties studied showed infection in the heads. This is the type of infection which is the most destructive, as the yield may be very materially reduced when the heads become infected. A discussion of this type of injury was given in one of the earlier papers of this series (10). It also is noteworthy that few of the wheat varieties which are commonly grown in the western portion of the United States where stripe rust is found are very susceptible to the rust. Exceptions to this are several of the club varieties, Early Baart, Jones Fife, and a few others.

A study of the foregoing results also will show that the varieties which have proved more or less resistant to leaf rust and stem rust have not shown, in every case, a similar resistance to stripe rust. Notable examples of this are several of the durum wheats which have been shown to be resistant to most strains of *Puccinia graminis tritici*. Khapli (C. I. 4013), an emmer which Hayes, Parker, and Kurtzweil (6) found resistant to all biologic forms of stem rust thus far isolated, is not especially resistant to the strains of stripe rust with which it has been inoculated. Jenkin and Sampson (11) state that comparatively few of the wheat varieties which they tested were resistant to both black rust (*Puccinia graminis*) and yellow rust (*Puccinia glumarum*).

Hiltner (9, p. 83) reports that in Germany spring wheat suffers more than winter wheat from the attack of *P. glumarum*. He also states that the club varieties as a class appear to be especially susceptible and that those varieties with broad leaves were not so often attacked by the rust. Von Kirchner (12) gives 20.4 per cent as the average stripe-rust infection on winter wheat for a number of years, while spring wheat for the same number of years showed only 16.2 per cent infection. Jenkin and Sampson (11) state that autumn varieties were found to be more susceptible to black rust and the spring varieties to yellow rust. Schneiderhan, in the unpublished report of the Sherman County Branch Station, Moro, Oreg., for 1916, reports that when certain varieties were grown as both spring and winter wheats, those sown in the fall developed the larger percentages of infection of stripe rust.

Examination of Tables III and IV shows that leaf infection in the seedling stage usually was much greater in spring-sown wheat. Infection at heading time, on the contrary, was in most cases much greater in winter wheat. It seems reasonable to suppose that both seasonal and regional differences in climate will determine to a certain extent whether fall-sown or spring-sown wheat becomes more heavily infected with stripe rust.

Histological studies of resistant and susceptible varieties of wheat attacked by stripe rust have not been made. The general external macroscopic evidences of resistance appear to be similar to those described by Stakman (17) for *Puccinia graminis tritici* E. and H. and by Parker (15) for *Puccinia graminis avenae* E. and H. Plates 3 to 5 illustrate the typical effect of *P. glumarum tritici* upon resistant hosts. Large areas of killed tissue develop on the portions of the leaves inoculated, followed by the production of very few if any uredinia. Upon varieties which are moderately resistant, urediniospores often are produced in abundance but no spread of the rust occurs from the parts of the leaf inoculated, and these portions are soon killed.

Parker (15) interprets purple blotches adjacent to the uredinia as evidence of resistance of oats to *P. graminis avenae*. As indicated in Table II and as illustrated in Plate 3, A, dark brown spots often develop on certain grass hosts when inoculated with urediniospores of *P. glumarum tritici*. Similar brown discoloration often appears around the edge of the uredinia on fairly susceptible grasses such as *Bromus sterilis*, *Bromus stichensis*, and others. This type of reaction has been noted only on certain species of grasses. Parker (15) also found that the production of telia of crown rust on seedlings of oats in the greenhouse was an indication of resistance. Although in a few cases telia have developed in the greenhouse upon wheat seedlings in connection with the work herein reported, this has been interpreted as being due to the effect of certain environmental conditions upon the host rather than as a sign of resistance.

SUMMARY

Field collections of *Puccinia glumarum* in the western part of the United States have been made on wheat, barley, rye, spelt, and emmer, as well as on 33 wild grasses.

It has been shown by artificial inoculation that the rust also will infect 26 additional grass hosts. This makes a total of 59 species of wild grasses which are hosts for this rust as it occurs in the United States.

The common specialized variety of stripe rust in the United States is the one peculiar to wheat, *P. glumarum tritici* Erikss. and Henn. Field observations indicate that the variety developing on barley, *P. glumarum hordei* E. & H., also occurs in this country.

The specialized variety from wheat also will infect rye moderately and barley slightly. Inoculation experiments have shown that this variety also will infect 47 wild grasses. This list includes 19 species of *Bromus*; 11 species of *Agropyron*; 7 species of *Hordeum*; 7 species of *Elymus*, and one species each of *Hystrix*, *Phalaris*, and *Sitanion*. Stripe rust has been collected in the field on twelve additional grass hosts, but it has not yet been possible to ascertain if these also are hosts for the specialized variety from wheat.

There has been some evidence that there are several strains of the different grass species which react differently to the same variety of the rust. There has been some indication also that there are two or more strains or specialized forms of *P. glumarum tritici*.

Varieties of wheat and wheat allies to the number of 163 have been tested for resistance to stripe rust in a rust nursery at Corvallis, Oreg., where an epiphytotic of this rust was produced artificially each year for three years. All of these varieties were grown for two years and part of them for three years. The results of these experiments are presented in tabular form.

Ninety-two varieties of wheat have been tested for resistance to stripe rust in the greenhouse. Some of these were studied three years, some of them in two years, and some of them in only one year. The results of these experiments are given in tabular form. With few exceptions the results of the field and greenhouse studies have agreed quite closely.

There is a very marked difference in the susceptibility of various wheat varieties to stripe rust. More of the common wheat varieties appear to be resistant to stripe rust than are resistant to stem rust. When more strains of stripe rust are tried this may not continue to be the case. Comparatively few of these varieties which were studied became infected

in the head under the conditions of the experiment. Varieties which developed head infection were greatly reduced in yield.

Leaf infection in the seedling stage has been more severe in spring-sown wheat. Leaf infection at heading time has been more severe in fall-sown wheat.

Several varieties have proved very resistant to the strains of the rust studied. Resistance is evidenced by the development of large areas of killed tissue in the portions of the leaves inoculated, followed by the production of few or no uredinia.

Dark brown blotches and browning around the edges of inoculated areas have developed upon certain grass hosts. This characteristic appears to be specific for certain grasses and has not been considered a general sign of resistance.

Telia have been formed in the greenhouse in a few cases under certain conditions. This was thought to be due to the conditions surrounding the host and was not regarded as a sign of resistance.

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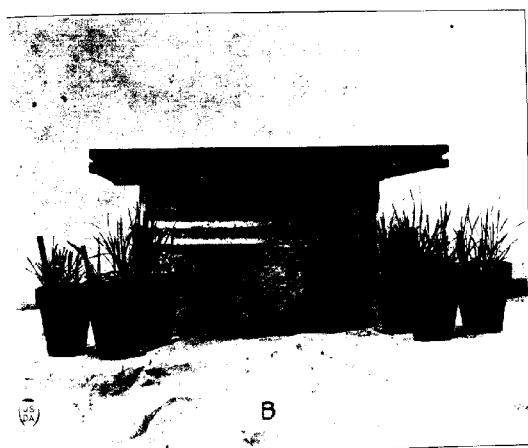
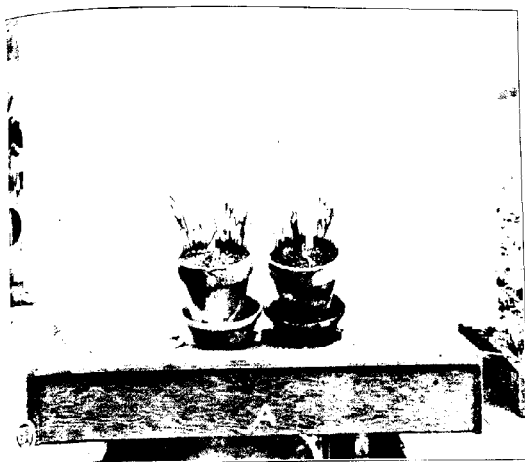
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PLATE 1

Method of growing the wheat seedlings for study of specialized races.

A.—Bell jar and battery jar used as incubation chambers, and pots containing wheat seedlings, showing method of separating the plants in each pot into two groups, one group being inoculated and the other used as control.

B.—Tub covered with window sash, used as an incubation chamber. Half the plants in the pots were inoculated, the pot placed in the tub in about 2 inches of water and the tub covered with the sash for 48 hours.



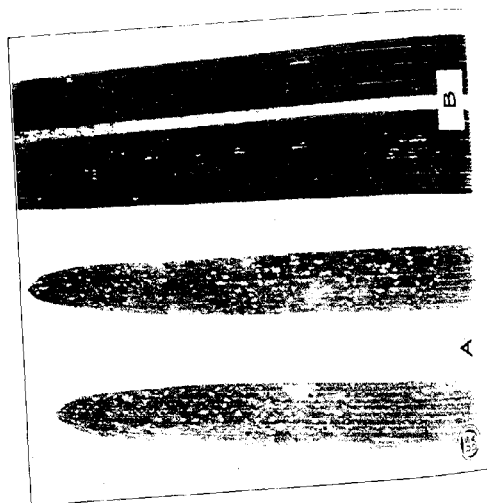


PLATE 2

Normal development of uredinia of *Puccinia glumarum tritici* on wheat leaves.

A.—Distal portion of a leaf of a seedling of Chul, showing abundant infection and production of uredinia.

B.—Portion of an older leaf of Chul, showing very abundant infection in the form of a single, longitudinal stripe.

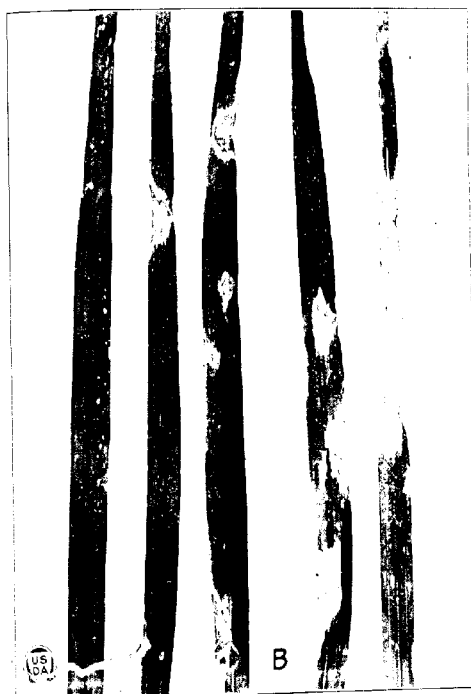
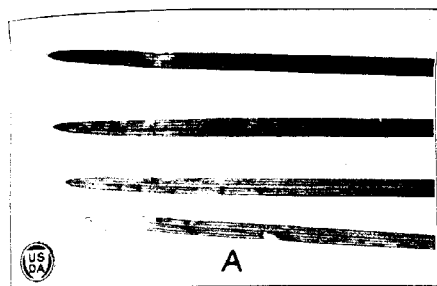
C.—Portion of a leaf of Little Club wheat, showing abundant infection and production of uredinia.

PLATE 3

Portions of inoculated leaves showing flecks or areas of tissue injured or destroyed by the fungus but no permanent infection resulting. This condition represents grade 0 in the five gradations of susceptibility to infection by *Puccinia glaucomaria tritici*.

A.—Portions of mature leaves of *Bromus carinatus* showing distinct brown blotches

B.—Portions of mature leaves of Red Russian wheat showing large spots of killed tissue.



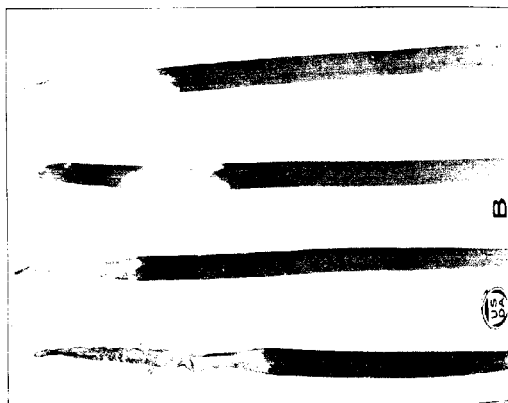
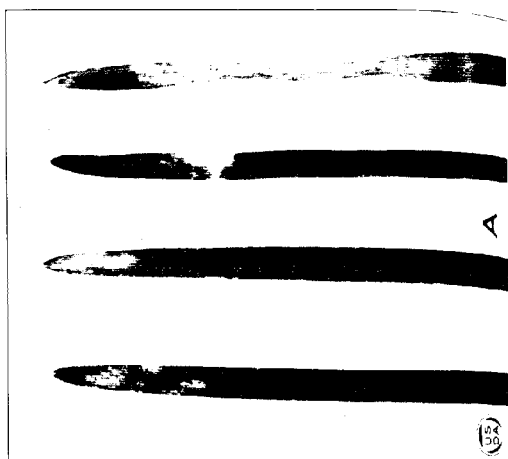


PLATE 4

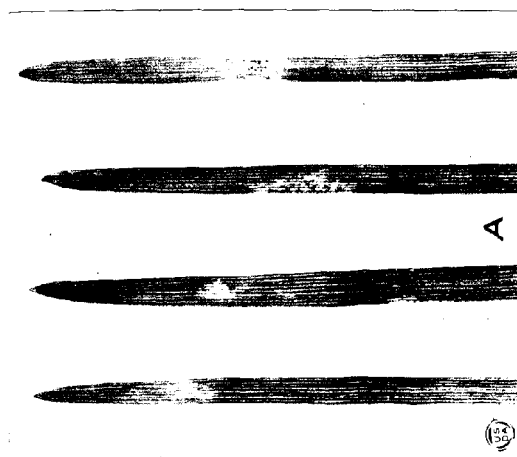
Portions of inoculated leaves showing flecks or areas of tissue injured or destroyed by the fungus but no permanent infection resulting. This condition represents grade 5 in the five gradations of susceptibility to infection by *Puccinia glumarum tritici*.
A.—Distal portion of leaves of Barletta wheat (C. I. No. 3297).
B.—Distal portion of leaves of Einkorn (C. I. No. 2433).

PLATE 5

Portions of inoculated leaves showing uredinia few or minute, usually surrounded by areas of dead or discolored tissue. This condition represents grade 1 in the five gradations of susceptibility to infection by stripe rust.

A.—Distal portions of leaves of Sonora wheat (C. I. No. 3036).

B.—Distal portions of leaves of Einkorn (C. I. No. 2973) 18 days after inoculation.



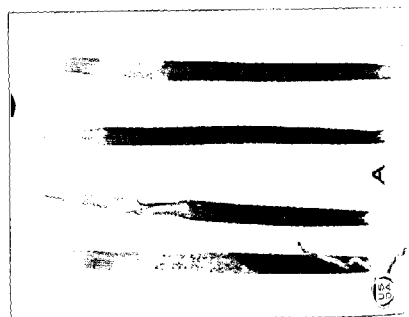
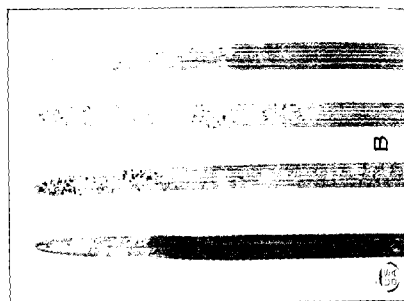


PLATE 6

Portions of inoculated leaves showing effects of inoculation with *Puccinia glumarum* Berk.

A.—Distal portions of leaves of Red Winter spelt (C. I. No. 1772), showing normal uredinia, but few and scattered, with leaf tissue abundantly discolored. This condition represents grade 2 of the five gradations in susceptibility to infection by stripe rust.

B.—Distal portions of leaves of *Bromus sterilis*, showing uredinia normal and moderately abundant, with but little discoloration of leaf tissue. This condition represents grade 3 of the five gradations in susceptibility to infection by stripe rust.

C.—Distal portion of leaves of Black Winter cinmer, showing uredinia normal and abundant, scattered uniformly over surface of leaf, with no discoloration in the early stages of infection. This condition represents a grade of 4, or very susceptible, in the five gradations in susceptibility to infection by stripe rust.

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JOURNAL OF AGRICULTURAL RESEARCH

VOL. XXV

WASHINGTON, D. C., SEPTEMBER 8, 1923

NO. 10

ORIGIN AND CONTROL OF APPLE-BLOTCH CANKERS¹

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INTRODUCTION

On account of the great significance of the twig cankers as a means of overwintering and source of early infection of the apple-blotch fungus (*Phyllosticta solitaria* E. and E.), knowledge of the mode of origin of these cankers is highly important. Likewise any new light on methods of canker prevention and eradication is much to be desired.

The identity and significance of the blotch cankers were discovered about the same time by Scott and Rorer (14)³ and by Sheldon (16), and petiole lesions were described by Sheldon and later by Scott and Rorer (15), who made an incidental observation of peculiar interest. They found a large percentage of the fruit buds in an orchard of Limbertwig, Missouri, and Ben Davis trees in Arkansas being killed in midsummer and attributed this in part to the apple-blotch fungus (15, p. 11) which according to their observations and cultural work "extended down from diseased leaf petioles into the twigs at the base of the buds, which were soon killed." Apparently, no significance was attached to this phenomenon in connection with the origin of cankers, since they mention spore infection of the twigs.

Lewis (10, p. 528, 533), who studied this disease on the Missouri variety in Kansas, states in connection with fruit spur cankers that "the fungus sometimes enters from the leaf stem, and at other times through the new growth just below the bud," and in connection with the importance of leaf infection he mentions the "possible infection of the twig from the petiole."

Roberts (12, 13) was able to produce cankers on young twigs and watersprouts by spraying with a water suspension of the spores, but was unable to infect older branches in this way and also was unable to cause infection of twigs by wound inoculation. These results would indicate that cankers are the result of germ tube infection through the uninjured epidermis of very young wood.

A study of the blotch cankers on the Northwestern variety at Mooresville (orchard of Mr. D. B. Johnson) and Knightstown (orchard of Mr. J. B. Hamer), in central Indiana, from 1919 to 1922, and on the Oldenburg variety at Mitchell, in southern Indiana, in 1921 and 1922, indicates that a large percentage of the cankers on twigs are the result of invasion from infected petioles rather than of direct spore infection (7). The

¹ Accepted for publication June 25, 1923. Contribution from the Botanical Department of Purdue University Agricultural Experiment Station, La Fayette, Ind.

² The writer wishes to acknowledge his indebtedness to Prof. H. S. Jackson for helpful suggestions and to Prof. Laurence Greene, Mr. C. E. Baker, and Mr. R. A. Simpson for their cooperation.

³ Roberts (12) reads by number (italic) to "Literature cited," p. 417-418.